ESC201T : Introduction to Electronics

HW9: Solution

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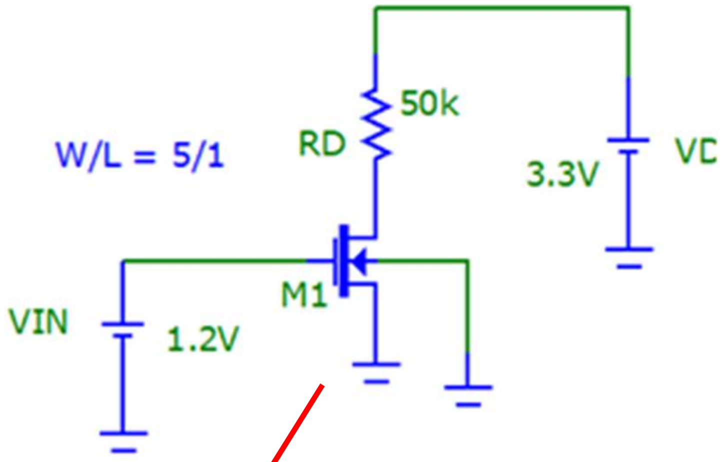
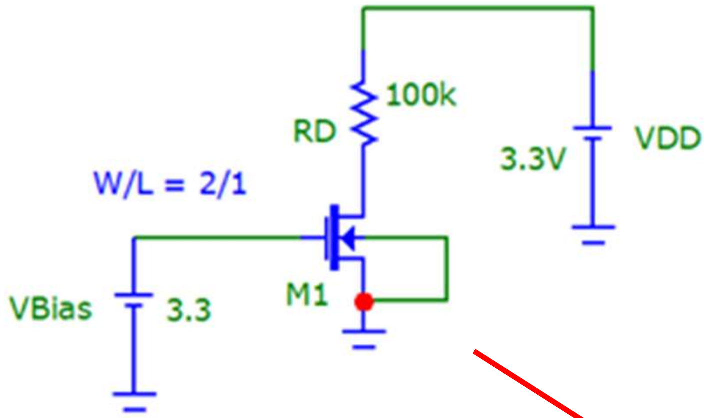
Q.1 Determine the drain current and drain-source voltage for the two circuits shown below.

Assume that $KP_N = 100\mu A/V^2; V_{THN} = 1V; \lambda_n = 0V^{-1}$





Assuming saturation mode :

$$ids(vgs) := kpn \times \frac{W}{L} \times \frac{(vgs - vthn)^2}{2}$$

$$ids(vgs) = 1 \times 10^{-5}$$

$$vds := vdd - ids(vgs) \times RD$$

$$vds = 2.8 \qquad vdsat = 0.2$$

So assumption is correct

Assuming saturation mode :

$$ids(vgs) := kpn \times \frac{W}{L} \times \frac{(vgs - vthn)^2}{2}$$

$$ids(vgs) = 5.29 \times 10^{-4} \qquad vds = -49.6$$

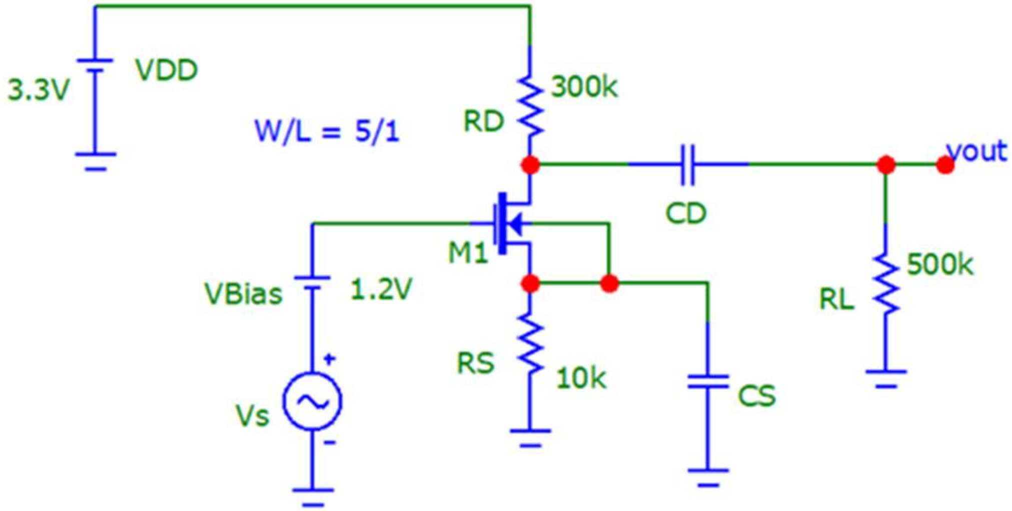
So Transistor is in Linear mode

$$ids := kpn \times \frac{W}{L} \times (vgs - vthn) \times (vdd - ids \times RD)$$

$$ids = 3.23 \times 10^{-5} \qquad vds := vdd - ids \times RD = 0.07$$

(Units are Ampere and Volt)

Q.2 Analyze the circuit shown below to determine the voltage gain of the amplifier. Determine the gain if the capacitor C_S is removed from the circuit. Assume the same MOS parameters as in Q.1



<u>dc or Bias point or Quiescent point</u>

(Units are Ampere and Volt)

Assuming saturation mode

$$ids(vgs) := kpn \times \frac{W}{L} \times \frac{(vgs - vthn)^2}{2}$$

$$vgs := Vbias - ids \times RD$$

We will get 2 values

$$ids1 = 7.464 \times 10^{-5}$$

$$vgs1 := vthn + \sqrt{\frac{2 \times ids1}{kpn \times \frac{W}{L}}}$$

$$vgs1 = 1.546$$

Not possible since VBias = 1.2

$$ids2 = 5.359 \times 10^{-6}$$

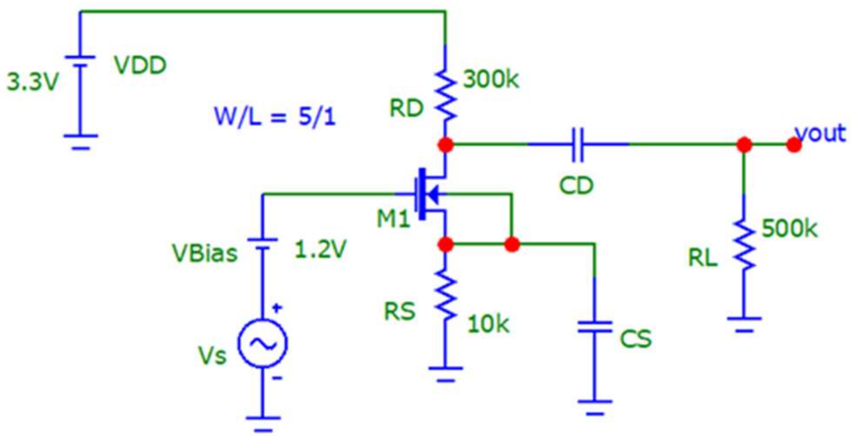
$$vgs2 := vthn + \sqrt{\frac{2 \times ids2}{kpn \times \frac{W}{L}}}$$

$$vgs2 = 1.146$$

This is fine V_{DSAT} =0.146V

$$vdd - ids2 \times RD = 1.692$$

So Tr. Is in SAT



Bias point:

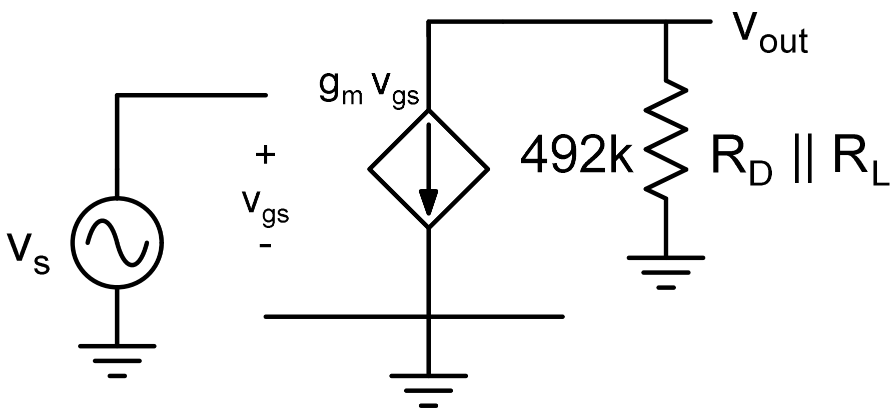
$$\mathrm{vgs2} = 1.146 \qquad \mathrm{ids2} = 5.359\times 10^{-6}$$

$$\mathrm{vdd} - \mathrm{ids2} \times \mathrm{RD} = 1.692$$

$$g_m = \sqrt{2I_{DS} \times KP_N \times \frac{W}{L}} = 7.3 \times 10^{-5}\Omega^{-1}$$

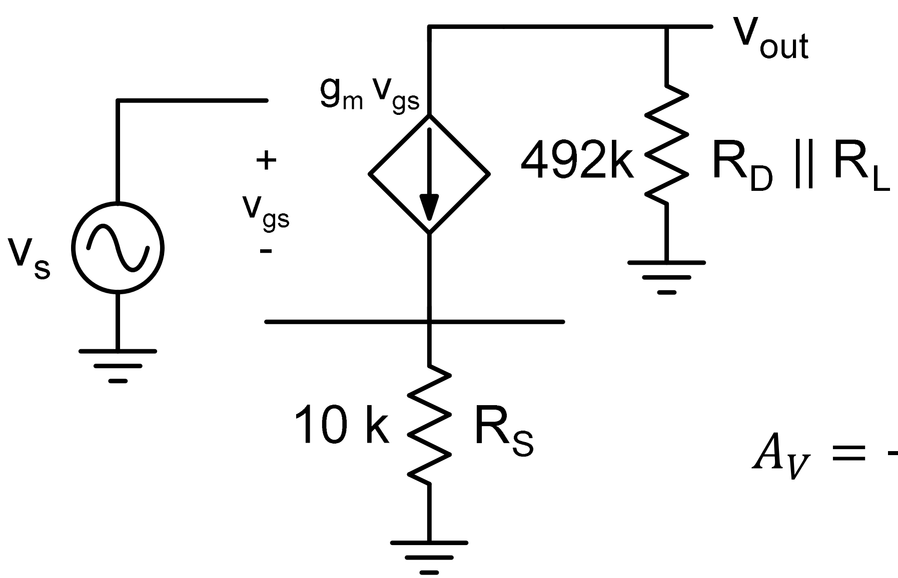
ac or small signal analysis

Capacitors acts as short resulting in the following equivalent circuit



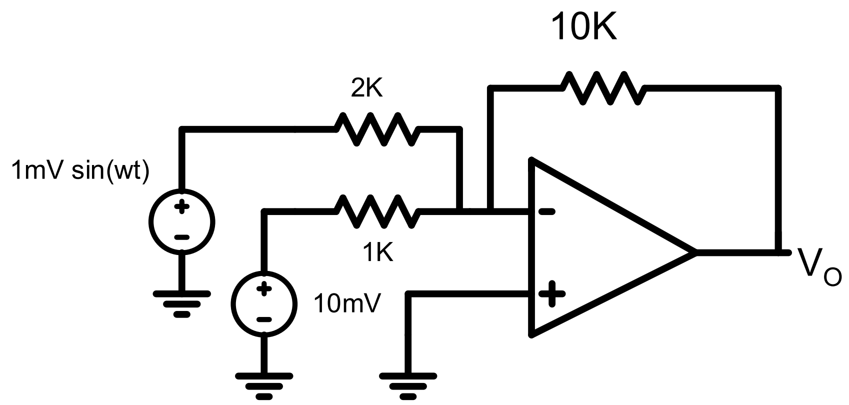
$$A_V = -g_m \times R_D \| R_L = -36$$

Removing the capacitor Cs does not alter the bias point and thus gm also remains same. The ac equivalent circuit now becomes

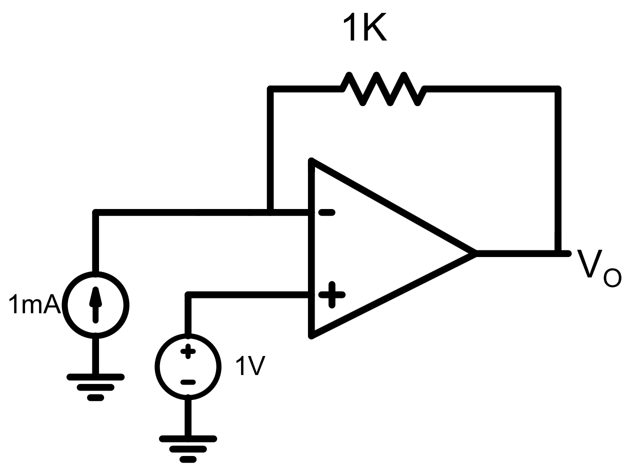


$$A_V = -\frac{g_m}{1 + g_m \times R_S} \times R_D \| R_L = -20.78$$

Q.3 Determine the output of the ideal opamp circuits shown below



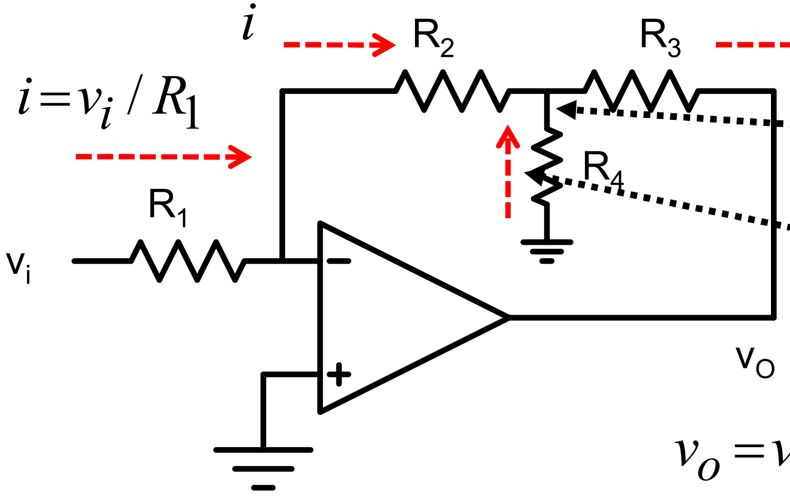
$$v_O = -\{\frac{10K}{1K}\times 10mV + \frac{10K}{2K}\times 1mV\sin(\omega t)\}$$
$$= -\{0.1 + 5\times 10^{-3}\sin(\omega t)\}$$



$$v_+ = v_- = 1V$$

$$\frac{1 - v_O}{1K} = 1mA \qquad v_O = 0V$$

$i = v_i / R_1$



$i_o = i + i_x$

$v_x = -iR_2 = -R_2 / R_1\, v_i$

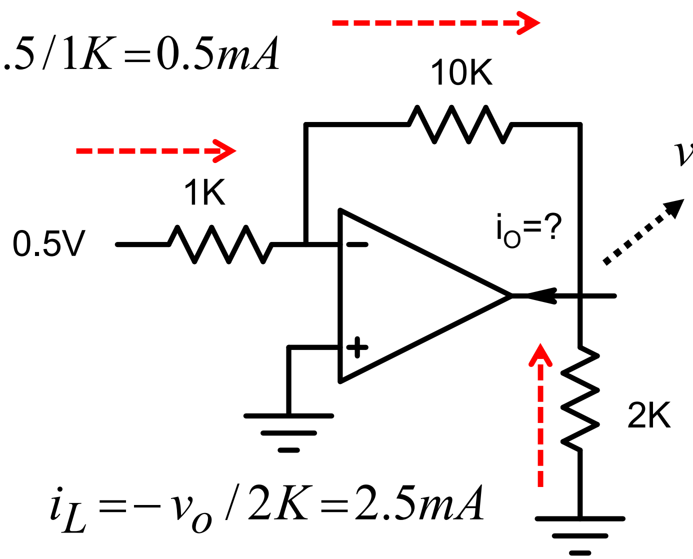
$i_x = -v_x / R_4$

$v_o = v_x - i_o R_3$

$v_o = -\frac{R_2}{R_1}\left(1 + \frac{R_3}{R_4} + \frac{R_3}{R_2}\right) v_i$

$i_s = 0.5mA$

$i_s = 0.5 / 1K = 0.5mA$



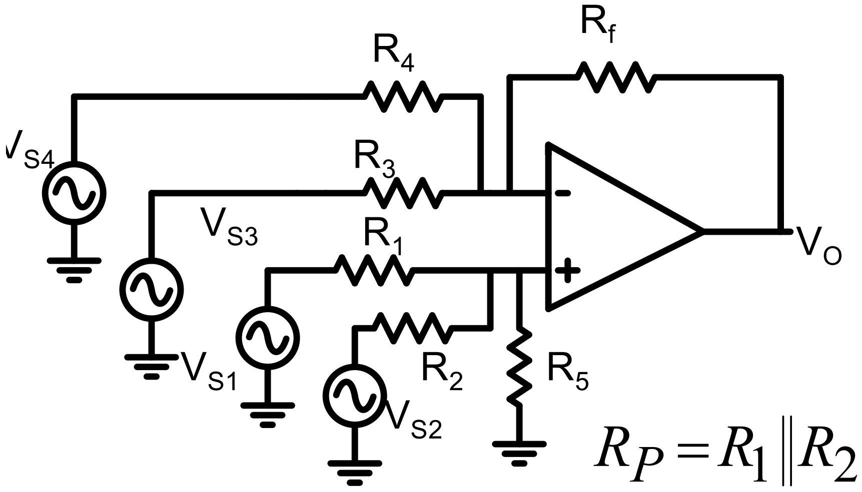
$v_o = -i_s \times 10K = -5V$

$i_o = i_S + i_L = 3mA$

$i_L = -v_o / 2K = 2.5mA$

Q.4 Design an opamp circuit that would generate the following output voltage where Vs1, Vs2, Vs3 and Vs4 are input voltages

$$V_O = 2v_{s1} + 4v_{s2} - 8v_{s3} - 10v_{s4}$$



$$R_P = R_1 \| R_2 \| R_5$$

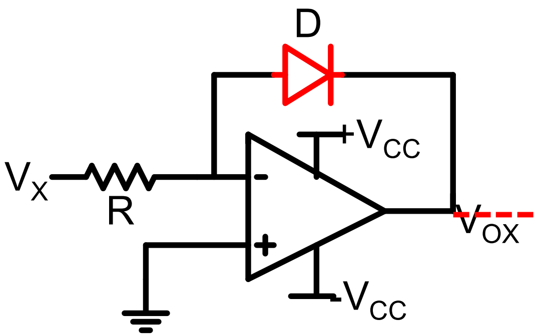
$$v_o = -(\frac{R_f}{R_3})v_{s3} - -(\frac{R_f}{R_4})v_{s4} + (1+\frac{R_f}{R_3\|R_4}) \times \frac{R_P}{R_1}v_{s1} + (1+\frac{R_f}{R_3\|R_4}) \times \frac{R_P}{R_2}v_{s2}$$

Choose : $R_f = 10K \quad \Rightarrow R_3 = 1.25K \quad \Rightarrow R_4 = 1K$

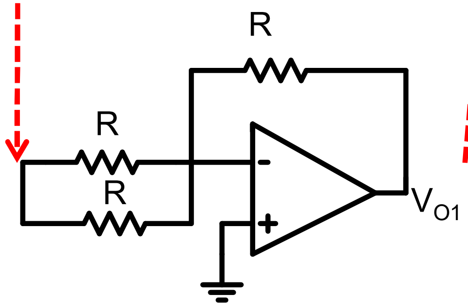
$$\Rightarrow \frac{R_P}{R_1} = 0.105 \qquad \Rightarrow \frac{R_P}{R_2} = 0.211 \qquad \Rightarrow \frac{R_1}{R_2} = 2$$

Choose : $R_2 = 1K \quad \Rightarrow R_1 = 2K \quad \Rightarrow R_P = 0.211K \quad \Rightarrow R_5 = 0.308K$

Q.5 Design an opamp circuit that can produce $V_O = K \times V_{IN}^2$ where Vin is the input voltage.

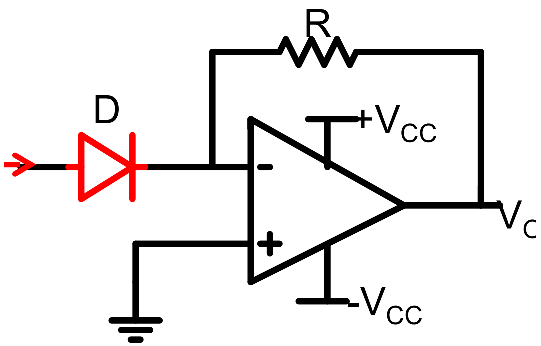


$$V_{OX} = -V_T \times \ln\left(\frac{V_X}{RI_S}\right)$$



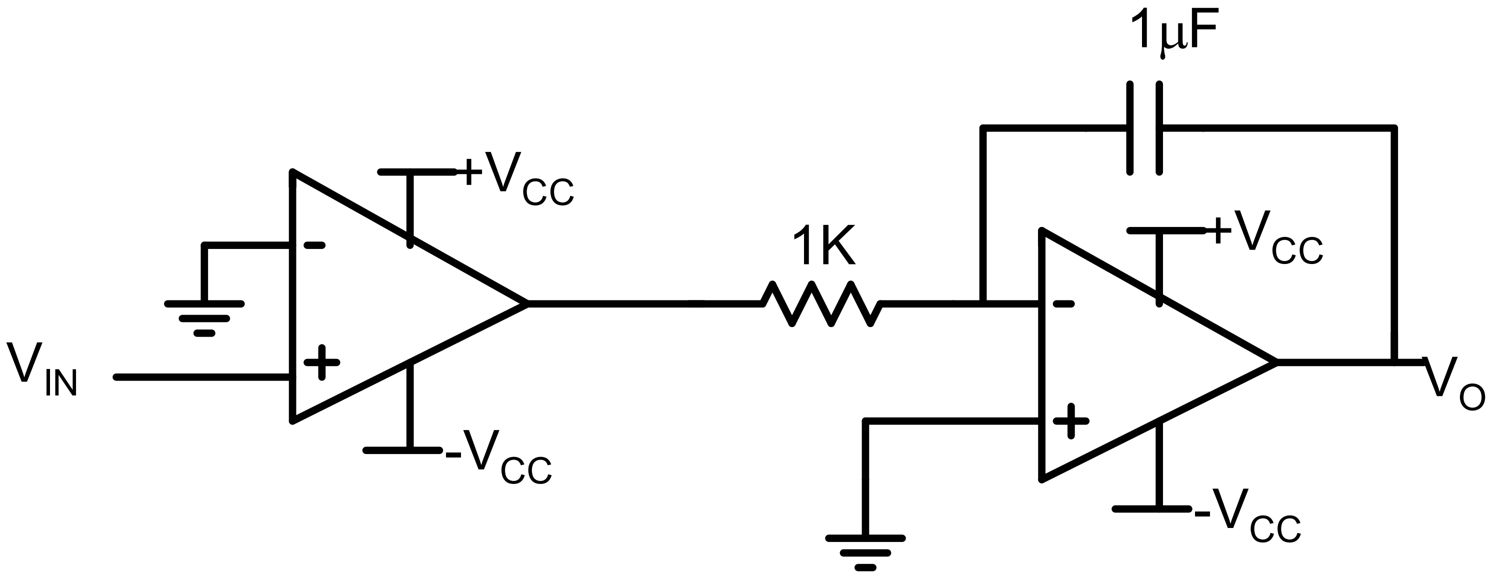
$$V_{O1} = V_T \times \left(\ln\left(\frac{V_X}{RI_S}\right) + \ln\left(\frac{V_X}{RI_S}\right)\right)$$

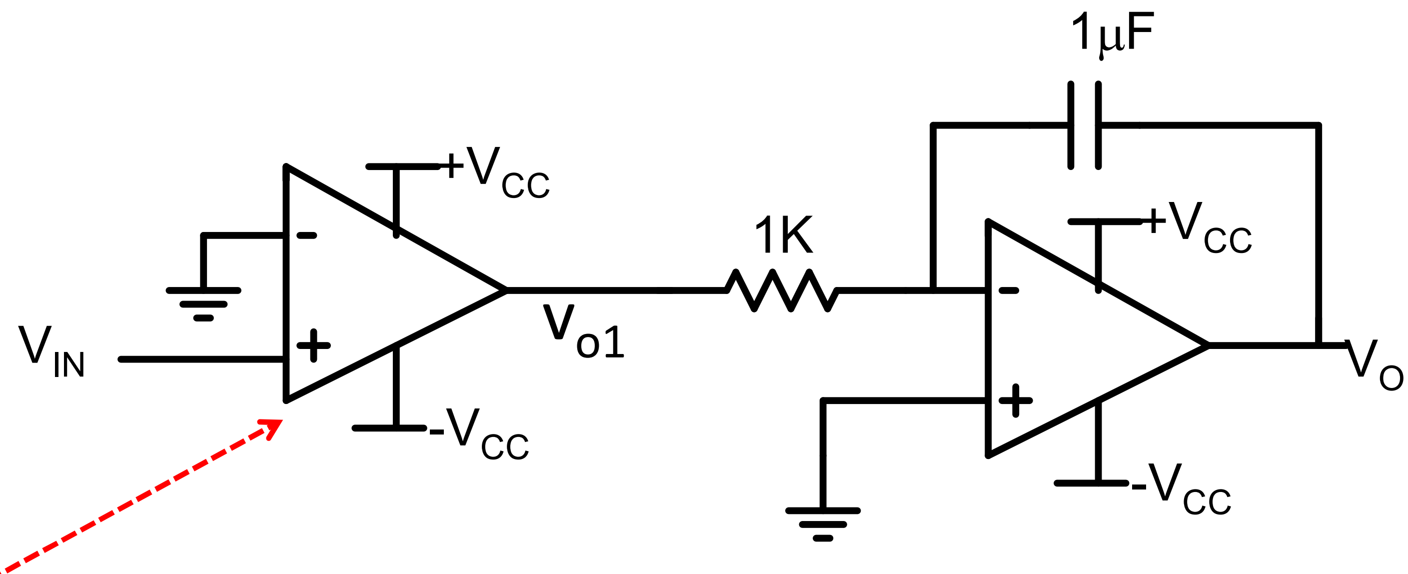
$$V_{O1} = V_T \times \ln\left(\frac{V_X^2}{R^2 I_S^2}\right)$$



$$V_O \cong -RI_S \times e^{\frac{V_{O1}}{V_T}} = -\frac{V_X^2}{RI_S}$$

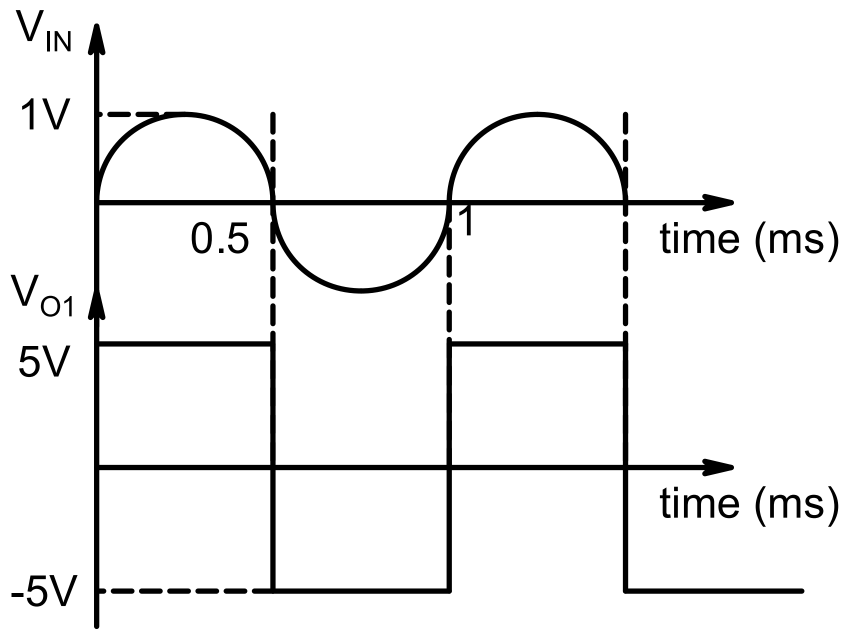
Q.6 Sketch the output voltage of the circuit shown below for $V_{in} = 1V\ Sin(2\pi ft);\ f = 1KHz$ and supply voltages of $\pm 5V$

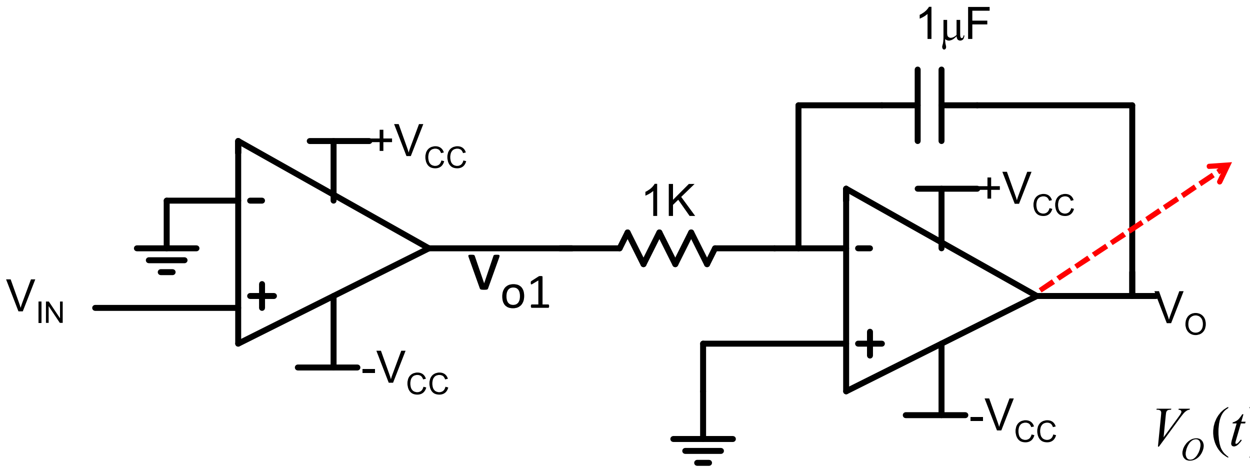




comparator

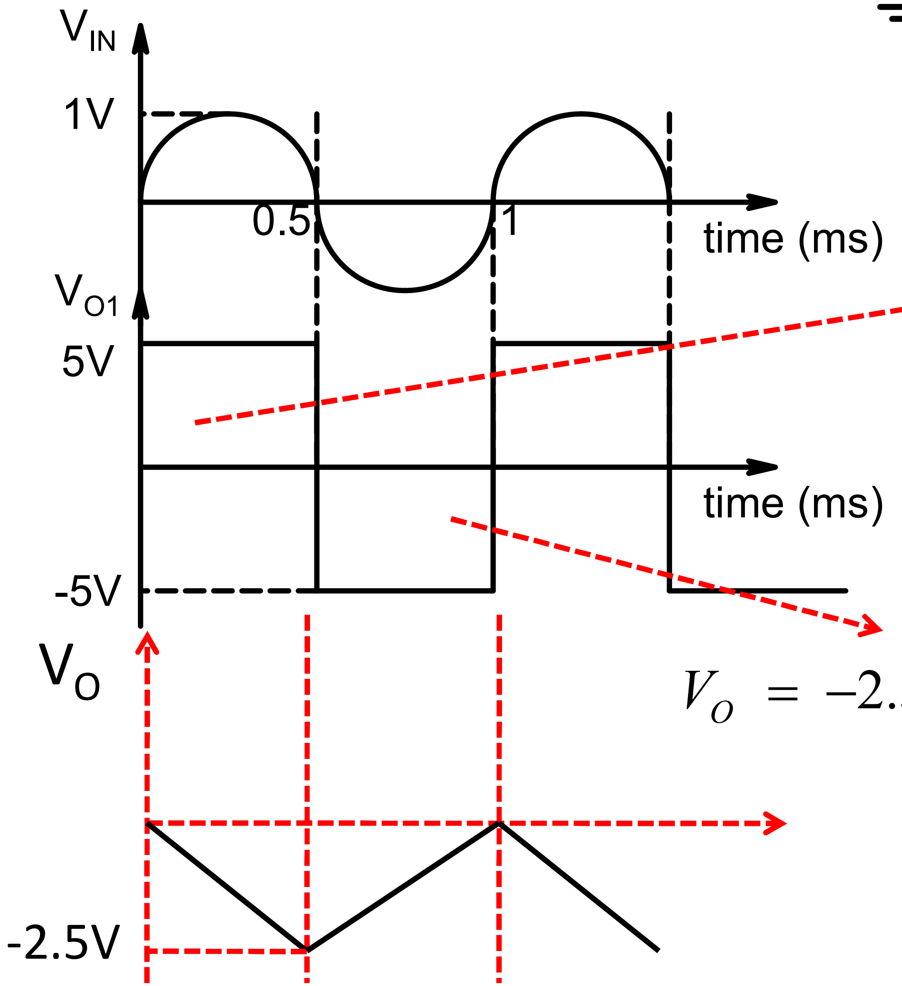
$$
\begin{aligned}
V_{O1} &= +5V \; if \; v_{in} > 0 \\
&= -5V \; if \; v_{in} < 0
\end{aligned}
$$





$$V_O(t) = -\frac{1}{RC}\int V_{o1}\,dt$$

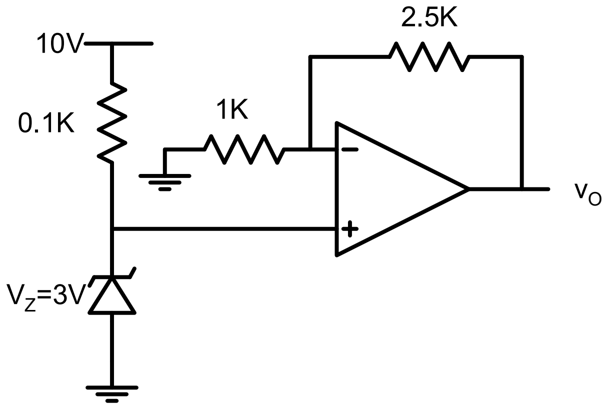
$$= -10^3 \int V_{o1}\,dt$$

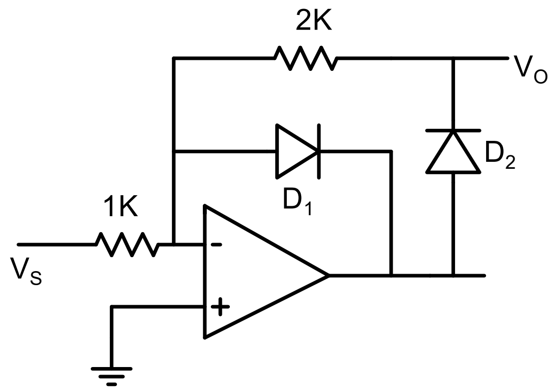


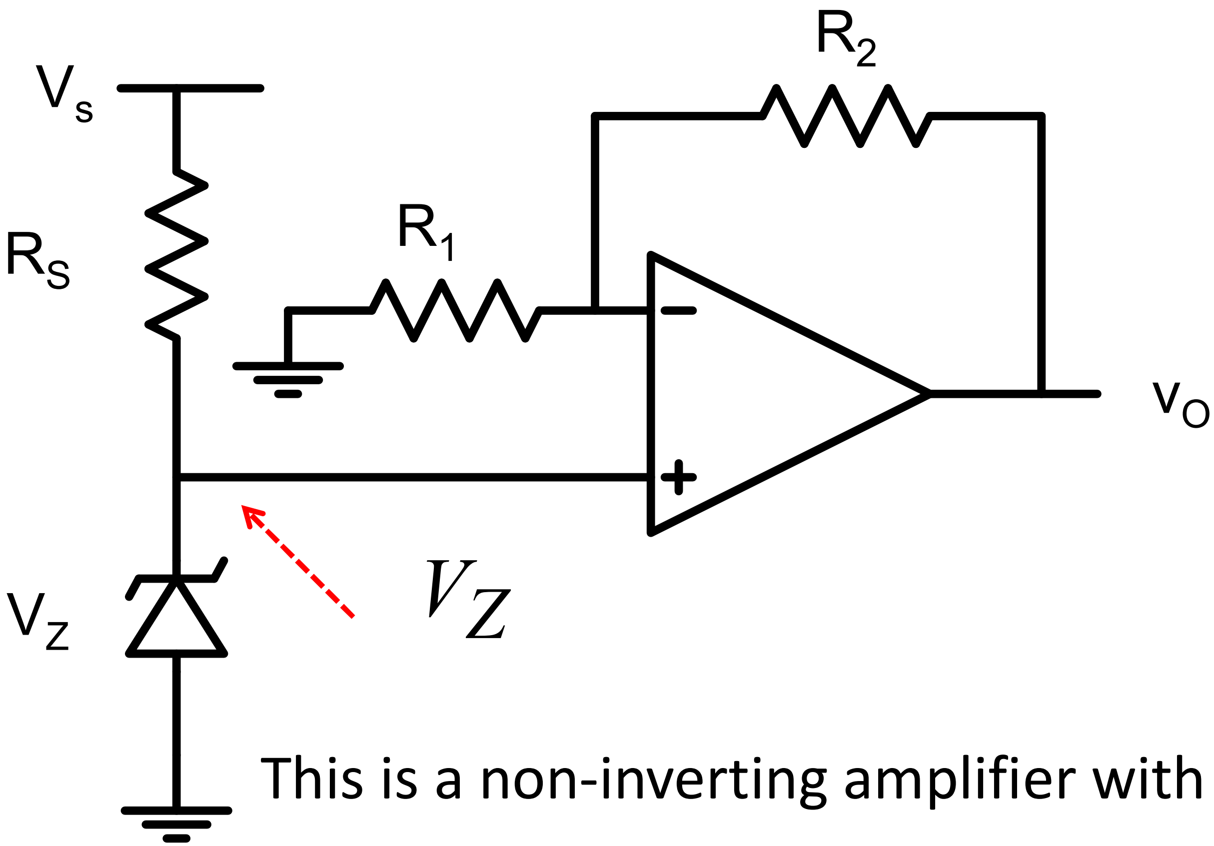
$$V_O = -5\times 10^3 \times t \;\; for\; 0 \le t \le 0.5ms$$

$$V_O = -2.5 + 5\times 10^3 \times (t - 0.5ms) \;\; for\; 0.5ms \le t \le 1ms$$

Q.7 Determine the output for the ideal opamp circuits shown below. For the circuit on the right assume that diodes have cut-in voltage of 0.7V. Analyze the circuit for Vs = 1V and Vs = -1V. For the transistor assume a current gain of 100. What is the usefulness of each of the circuits?



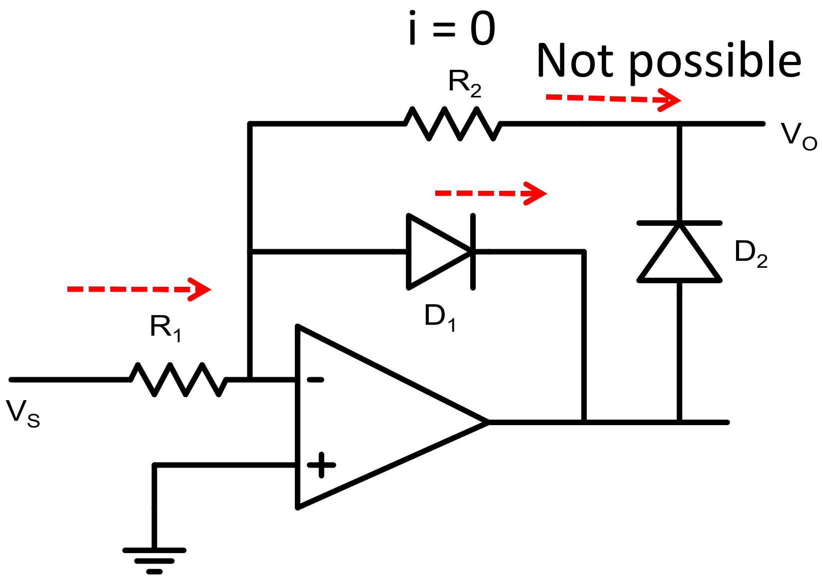




This is a non-inverting amplifier with V_Z as input

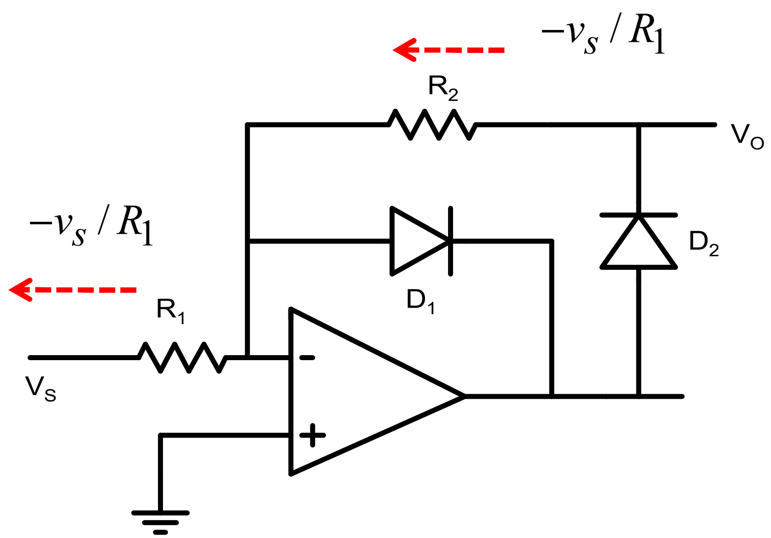
$$v_o = V_Z\left(1+\frac{R_2}{R_1}\right)$$

The circuit produces a constant output voltage Vo even though supply voltage may vary and thus acts like a voltage regulator.



$V_S > 0$

$V_O = 0$



$V_S < 0$

$$\frac{v_o}{v_S} = -\frac{R_2}{R_1}$$

The circuit acts like a rectifier